NASA CASE NO. MFS-28345-2

PRINT FIGURE 2

NOTICE

128.

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MSFC

NASA Case No. MFS-28345-2

PATENT APPLICATION ABSTRACT

TURBOMACHINERY SHAFT INSERT

This invention is directed to an insert for use in mounting the impeller on the hollow shaft of the pre-burner pump of the high pressure oxygen turbopump used in the space shuttle main engine.

The insert 22 has a cylindrical portion 24 received within the bore at the end of the shaft 16. The impeller 12 is mounted on the outer diameter of the shaft 16 by means of a spline 15. The insert has an annular flange 32 extending in the direction opposite to the shaft, and this flange has an inner annular surface 34 and an outer annular surface 36. The flange 32 is received within a recess 38 in the impeller and the surfaces 34 and 36 engage corresponding surfaces 40 and 42 in the recess so as to form a double pilot for guiding and centering the impeller relative to the shaft. The insert also includes an elongated tubular portion 44 which has longitudinally extending slits 48 spaced about the circumference. The end of the insert has a series of hook-like tongues 50 which are squeezed into the bore of the impeller during assembly and snap radially outwardly into recesses 54 in the wall of the bore when the impeller is properly seated axially during assembly.

The novelty of the invention appears to lie in the double pilot arrangement for guiding and centering the impeller during assembly and low speed, and also at high speed. It also solves the piloting problem of overhung impellers. The double pilot arrangement prevents spline friction from becoming a whirl driver as the impeller rotates.

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Employer: NASA/Marshall Space Flight Center

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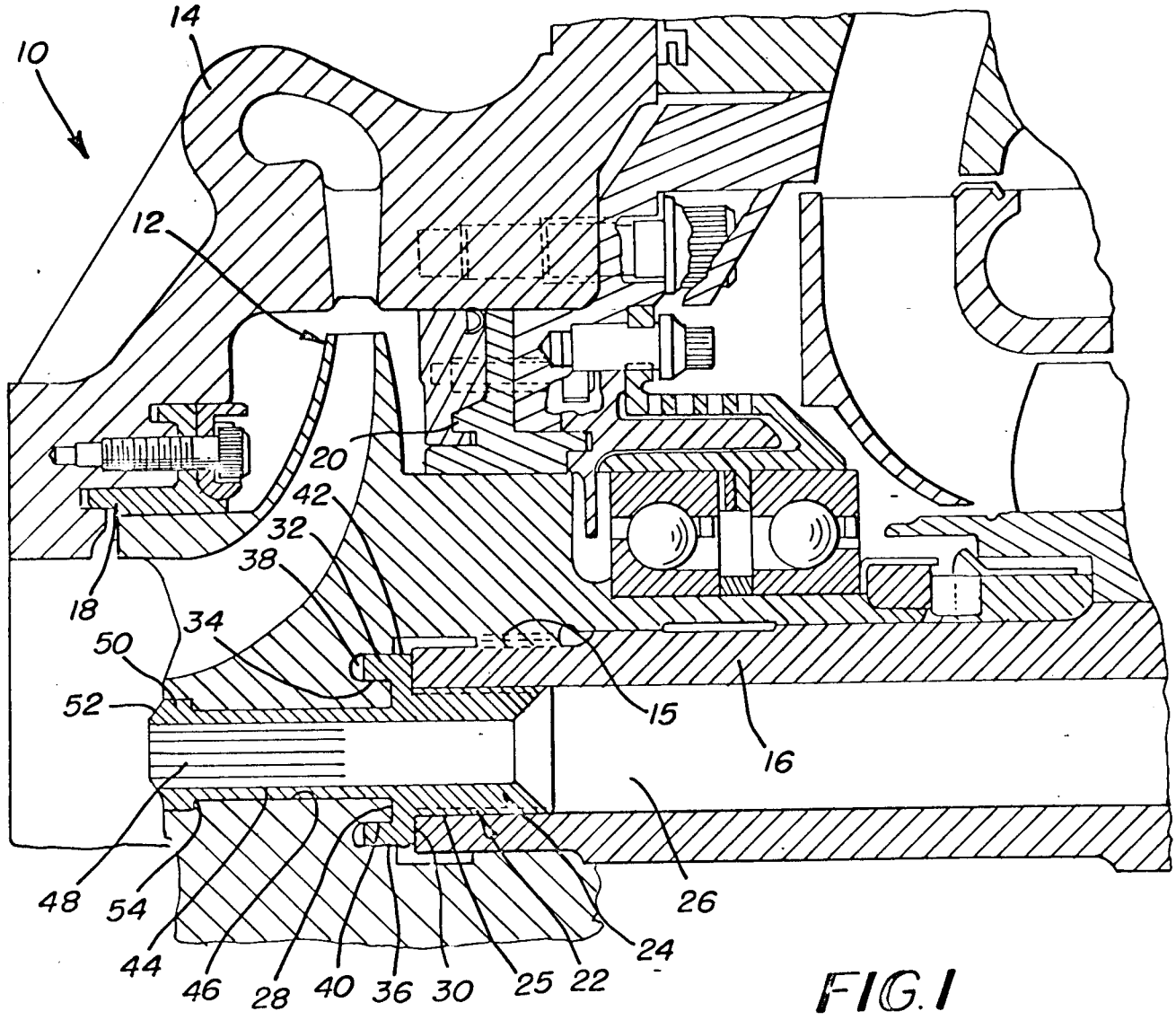
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FIG. 1

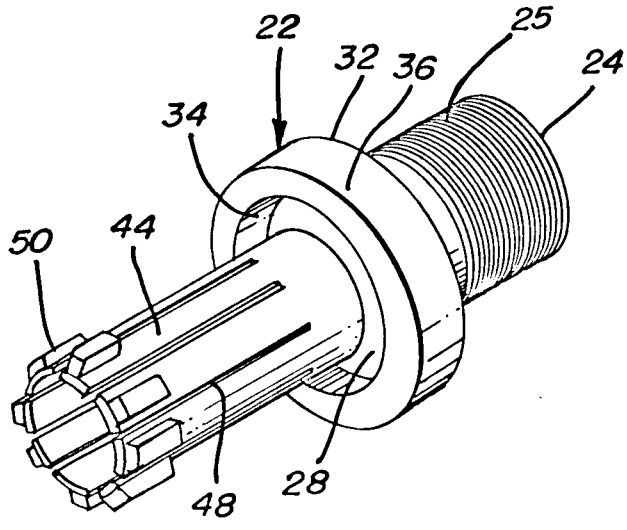
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FIG. 2

TURBOMACHINERY SHAFT INSERT

ORIGIN OF THE INVENTION

BACKGROUND OF THE INVENTION

This invention relates to an insert for use with a disc or impeller mounted on a rapidly rotating hollow shaft such as utilized in high speed turbomachinery, and more particularly to an insert which aids in securing an impeller mounted in overhung fashion to a rotatably driven hollow shaft in high speed turbomachinery such as the high pressure oxygen turbopump of the space shuttle main engine, the insert having a pair of annular surfaces cooperating with receiving surfaces in the impeller to provide a double pilot remaining tight at all speeds to aid in the elimination of whirl instability in such turbomachinery.

The high pressure oxygen turbopump used in the space shuttle main engine uses duplex ball bearings, i.e., a pair of bearings mounted closely adjacent each other, near each end of the rotor. A damping seal such as that disclosed in U.S. Patent No. 4,545,586, adjacent the pump end of the rotor besides reducing leakage between the fixed and rotating portions also damps rotor lateral motion and thus shares the bearing load in the pump portion of the turbopump. The duplex bearings are each a pair of ball bearings having an axial preload force applied thereto to avoid ball skidding and wear. The preload is provided by a spring located between the outer races of each pair of duplex ball bearings. The ball bearing prevents seal rubbing and the damping seal

eliminates instability due to whirl, that is, the orbiting of the rotor shaft due to fluid forces acting to urge the shaft tangentially, when radially from the rotational center, creating an eccentric rotation.

Due to ball bearing wear the operational time of the high pressure oxygen turbopump of the space shuttle main engine is limited, thereby hindering the space shuttle program. The excessive ball bearing wear is a result of excessive lateral or side loads. Such side loads frequently may not be shared equally between the bearing units of one duplex bearing pair because of shaft bending, deformation of the bearing holders and other factors. The forces on the rapidly rotating impeller may cause the side loads on a single bearing to be in excess of twice the bearing axial preload, which is substantially greater than the generally recommended one-half or one-third loading. Thus, the balls are forced up and down the shoulders of the bearing races cyclically as the ball train rotates at approximately 43 percent of the shaft speed. These excursions of the balls cause ball skidding, excessive heating and excessive wear of the bearings. Additionally, during turbopump start-up and shut-down axial overloads are present which require that the balls have large contact angles to counteract these axial forces. On the other hand, the large lateral or side loads during operation require small contact angles if over-stress is to be prevented. Where the outer races are permitted to float and the balls have large contact angles, spinning of the outer races occurs and load shearing by the bearing with the damping seal is limited. Accordingly, compromises in the bearing design have been made which have resulted in the aforesaid limitations in bearing wear.

In copending United States patent application (NASA Case No. MFS-28345-1) there is proposed damping seals, damping bearings and support means for the ball bearings

of the rotor of such high speed machinery which reduces a substantial number of these problems by preventing tilting and spinning of the outer races; aids in supporting the shaft at low speeds; avoids and counteracts radial loading of the bearings while absorbing axial loads at high speed; and eliminates a substantial amount of the whirl driving forces. However, there are other whirl drivers in such high speed turbomachinery. For example, the impeller is rotatably connected to the shaft by a spline, and spline friction is a potential source for tangential forces which result in whirl instability. This is especially a problem where the impeller projects a substantial amount beyond the end of the shaft such as in the case with a centrifugal impeller of the type used in the high pressure oxygen turbopump of the space shuttle main engine.

SUMMARY OF THE INVENTION

Consequently, it is a primary object of the present invention to provide an insert for insertion into the end of a hollow rotating shaft for aiding in the mounting of a rotor such as an impeller on the shaft, the insert having means for securing the rotor thereto and for supporting the rotor during the entire speed range of the shaft.

It is another object of the present invention to provide an insert for the end of a hollow rotatable shaft to which an impeller or the like is secured, the insert having impeller securing means and a pair of annular support surfaces which engage cooperatively with surfaces within an annular recess in the impeller to provide a double pilot, one pilot being effective at assembly and low speeds, and the other being effective at high speeds.

Accordingly, the present invention provides an insert for a hollow rotatable shaft on the end of which an impeller or similar rotor is mounted, the insert having a first cylindrical portion receivable within the end of the shaft, a radially extending portion adjacent the end of

the shaft having an annular flange facing remote from the shaft and received within a recess in the impeller, the flange having radially inner and outer surfaces for engaging tightly radial walls of the recess, and a tubular extension which is receivable securely within a bore formed in the impeller. The tubular extension is hollow and includes axial slits for permitting the extension together with radially extending hook-like tongues thereon to be received within radial slots in the end of the bore to lock the impeller to the insert. The radially inner and outer surfaces of the tight fitting flange form a double pilot with the walls of the recess, the radially outer surface of the flange acting to guide and center the impeller relative to the shaft at assembly and low speed, while the radially inner surface acts to guide and center the impeller relative to the shaft at high speed.

BRIEF DESCRIPTION OF THE DRAWINGS.

The particular features and advantages of the invention as well as other objects will become apparent from the following description taken in connection with the accompanying drawings, in which: -

Fig. 1 is a partial cross sectional view of the high pressure pump portion of a turbopump incorporating a shaft insert constructed in accordance with the principles of the present invention; and

Fig. 2 is a perspective view of the insert of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, a partial cross sectional view of the high pressure pump portion 10 of a turbopump used in the space shuttle main engine is illustrated, the pump having an impeller 12 mounted within a shroud or housing 14. The impeller is connected by a spline 15 to a hollow shaft 16 open at the pump end thereof rotatably driven at a speed of approximately

30,000 rpm by a turbine (not illustrated) mounted on the shaft 16 remote from the pump portion of the turbopump. Annular damping seals 18 and 20 for restricting fluid leakage and damping rotor whirl are fastened between the rotatable impeller 12 and the fixed housing 14 adjacent the inlet and discharge portions of the impeller, the seals 18 and 20 being similar to the damping seals forming the subject matter of my aforesaid U.S. Patent No. 4,545,586, modified as described in accordance with my aforesaid copending application No. (NASA Case No. MFS-28345-1).

As aforesaid, the frictional forces of the spline connection 15 between the shaft 16 and the impeller 12 is a potential whirl driver. The damping seals attenuate the whirl, but it is desirable to prevent spline friction from becoming a whirl driver. To this end the present invention provides a hollow insert 22 having a first cylindrical portion 24 receivable within the hollow 26 at the end of the shaft 16 and secured therein by threads 25 or the like. The insert 22 includes a radially extending web 28 having a surface 30 thereof which abuts the end of the shaft 16. At the outer periphery of the web 28 an annular flange 32 is formed, the flange being defined by a cylindrical wall projecting in the direction facing remotely from the shaft 16 and having inner and outer annular surfaces 34, 36 respectively.

The flange 32 is received within a recess 38 in the impeller 12 spaced axially from the shaft 16, the recesses having inner and outer wall surfaces 40, 42 respectively which tightly abut the respective surfaces 34 and 36 of the flange 32 of the insert 22. The outer surface 36 of the insert acts as a low speed pilot against the surface 42 to guide and center the impeller 12 relatively to the shaft 16 at assembly and at low rotational speeds, while the inner surface 34 of the insert acts as a high speed

pilot with the surface 40 when centrifugal growth of the impeller occurs during high speed rotation of the turbopump. In contrast with prior art arrangements where the piloting or guiding became looser and less effective at high speed, in the arrangement here disclosed as the speed increases the piloting becomes stronger, i.e., tighter so that it is tight at low speeds and at high speeds.

Extending from the central portion of the web 28 in the direction away from the first cylindrical portion 24 is another cylindrical portion 44 which is received within the central bore 46 of the impeller 12. The portion 44 is tubular and has a series of longitudinally extending spaced apart slits 48 extending through the wall about its periphery, the slits extending substantially the entire length of the portion 44. The free end of the portion 44 has a plurality of spaced apart radially extending narrow tab or tongue members 50, the tongue members having inclined leading edges 52. The tongue members 50 are received within similarly shaped recesses or slots 54 in the wall of the bore 46 at the end of the impeller 12 and aids in mechanically securing the impeller on the shaft 16. During assembly, the slits 48 permit the tongue members 50 to be squeezed radially inwardly so that they may be received through the bore 46, aided by the inclined edges 52, until they reach the recesses 54 where they may then snap radially outwardly when the impeller is axially seated in the turbopump.

With the insert of the present invention, not only do the pilots eliminate spline friction from becoming a whirl driver as it provides a tight guide and centering means at all speeds, but it also overcomes the piloting problems of overhung impellers and other rotating discs, i.e., when the impeller or disc projects beyond the end of the shaft as in the preferred embodiment. Effectively, it is a

hollow bolt which secures the impeller 12 to the hollow shaft 16 by securely gripping the impeller 12 and the shaft 16, and guides and centers the impeller during the entire speed range thereof. Additionally, the tongues 50 also tighten in the recesses 54 as the speed increases.

Numerous alterations of the structure herein disclosed will suggest themselves to those skilled in the art. However, it is to be understood that the present disclosure relates to the preferred embodiment of the invention which is for purposes of illustration only and not to be construed as a limitation of the invention. All such modifications which do not depart from the spirit of the invention are intended to be included within the scope of the appended claims.

TURBOMACHINERY SHAFT INSERT

ABSTRACT OF THE DISCLOSURE

An insert for a hollow rotatable shaft on the end of which an impeller is mounted, the insert having a first cylindrical portion receivable within the end of the shaft. The insert includes a radially extending portion adjacent the end of the shaft having an annular wall including radially inner and outer surfaces for engaging tightly similar surfaces in a recess formed in the impeller to provide inner and outer pilot surfaces. The insert also includes a tubular extension which is received within a bore in the impeller, the tubular extension having spaced longitudinally extending slits for permitting the extension together with radially extending hook-like tongues thereon to be received within radial slots in the bore of the impeller to lock the impeller to the insert.